CHAPTER 6

THE ROLE OF SLEEP IN SUSTAINING INDIVIDUAL AND ORGANIZATIONAL EFFECTIVENESS

Nancy J. Wesensten, Thomas J. Balkin, and Gregory Belenky

Sleep is critical to sustaining operational performance. From a managerial point of view, sleep can be viewed as a logistical item, similar to water, food, fuel, ammunition, and computer resources. Skillful leaders will plan proactively for adequate resupply of sleep for themselves and their subordinates.

This chapter describes the contribution of sleep and time of day (circadian rhythms) to individual and organizational effectiveness. We use the term "organization" to mean any group organized to pursue a concrete objective, whether military or civilian. In the first section we present an overview of sleep deprivation effects on those cognitive or mental functions relevant to organizational effectiveness. Next, we discuss how travel across time zones and shift work impair sleep. Finally, we present solutions to the problem of sleep deprivation effects on organizational operations. [1]

CASE HISTORIES

How does sleep sustain operational performance? No one can dispute that falling asleep while on duty in an operational setting can lead to error, accident, and even catastrophe. What is less well understood is that sleep deprivation systematically degrades performance long before people become so sleepy that they fall asleep while working (e.g. driving an automobile, truck, etc.) In particular, sleep-deprived people will persevere, repeatedly attempting to implement failed solutions. Such sleep deprivation can have devastating effects on individual and organizational performance and effectiveness even while the persons involved are awake. Cases abound. For example, the Chernobyl nuclear reactor meltdown, the Exxon Valdez oil spill, the Challenger space shuttle disaster, and a tragic Gulf War friendly fire can all be partly linked to decisions made by people apparently awake but nonetheless suffering from a severe lack of sleep.

Let's look at the Challenger episode and the friendly fire incident in a little more detail.

Challenger Disaster

The U.S. Space Shuttle Challenger exploded on January 28, 1986, 73 seconds into its tenth flight, killing all seven crew members, including a civilian schoolteacher, Christa McAuliffe. From an engineering standpoint, the disaster was caused by the failure of an "O" ring in one of the solid rocket boosters to properly seat on ignition. The "O" ring lost flexibility because of the cold temperatures on the day of the launch. The failure to accurately evaluate the reliability of the "O" rings under prevailing weather conditions has been attributed to insufficient sleep on the part of NASA managers involved in the launch decision. Of the 3 high-level NASA managers involved, two had had less than three hours of sleep for 3 consecutive nights prior to the launch. [2]

Gulf War Friendly Fire Incident

This case history from the Gulf War illustrates sleep deprivation and time-of-day or circadian effects on organizational performance during military operations. During a night of total sleep deprivation, at approximately 0100 hours on February 26, 1991, a Second Armored Cavalry Regiment Bradley platoon screen line observed hot spots approaching on their thermal sights. They were uncertain as to whether these were friend or foe, and continued to observe. It was not until the lead vehicle actually entered their screen line that the Bradley crews concluded that the hot spots were a column of Iraqi armored personnel carriers. A brief firefight ensued, during which all the Iraqi vehicles were destroyed. However, during the firefight, the two Bradleys at the screen line right flank turned left and faced down their own line, but thought they were still facing the enemy. Perceiving that two Bradleys on the left flank were enemy vehicles, they proceeded to enfilade their own line with fire, destroying the two Bradleys on the left flank.

One of the authors of this chapter led the mental health team attached to the Second Armored Cavalry

Regiment and thus was able to reconstruct the friendly fire incident shortly after the event with all crew members present.[3] By their own self-report, the Bradley crews had obtained only 3-4 hours of sleep per night over the previous 5 days, and the firefight ensued during the early morning hours. Thus the crews were sleep-deprived and operating at a time of day when complex mental operations are at their worst. Despite this, the crew was still able to put the cross-hairs on the target and fire rounds accurately down-range—as evidenced by the destruction of the Bradleys on the left flank. Their *disorientation from the front* was the cause of this unfortunate friendly fire incident, because the crew was operating under the axiom that "if it's in front of us, it dies."

ORGANIZATIONAL AND MILITARY EFFECTIVENESS

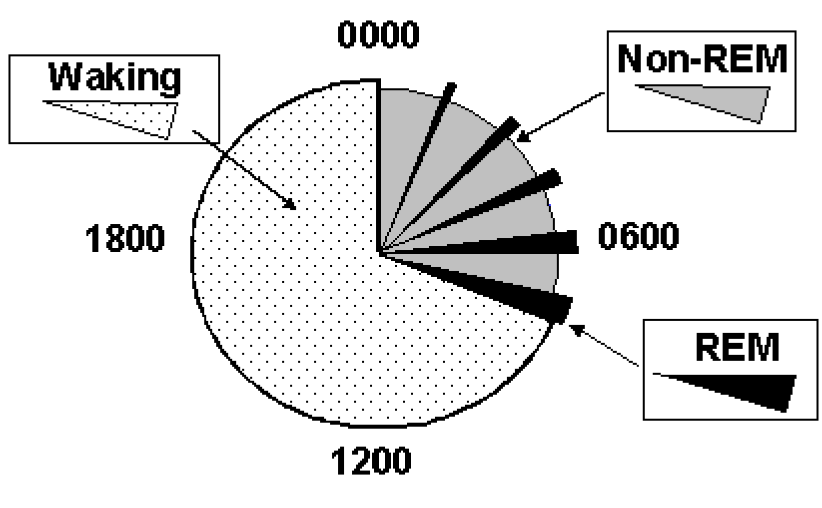
The case histories above illustrate that even as computer systems, weaponry, and organizations in general become more sophisticated, the individual and his or her performance remain critical to the success of organizational operations, both military and civilian. In its most basic form, effectiveness in any operational environment depends upon the person making the correct decision within a limited time.

Factors known to shape operational effectiveness, at both the individual and group or unit level, include experience, training, fitness, morale, leadership, cohesion, personal and family considerations, and such physiological factors as load, hydration, nutritional status, and sleep. We are just beginning to appreciate the impact of sleep on individual and organizational effectiveness. The two case histories bore all the marks of the effects of sleep deprivation on mental performance.

SLEEP––THE BASICS

Figure 1 depicts the 24-hour sleep-wake cycle in a person who sleeps from midnight to 0800, which is the daily amount considered optimal for sustaining maximal mental performance indefinitely. Stage 1 sleep, the lightest sleep stage, has little or no value for sustaining mental operations. During the primary sleep period, sleep stages alternate between REM (rapid eye movement) and non-REM sleep. In ways that we are now just beginning to understand, this combination of REM and non-REM sleep sustains complex mental operations during the ensuing period of wakefulness. Currently there is no evidence that recuperation after REM and sleep differs form that after non-REM.

Figure 1. The 24-Hour Sleep/Wake Cycle



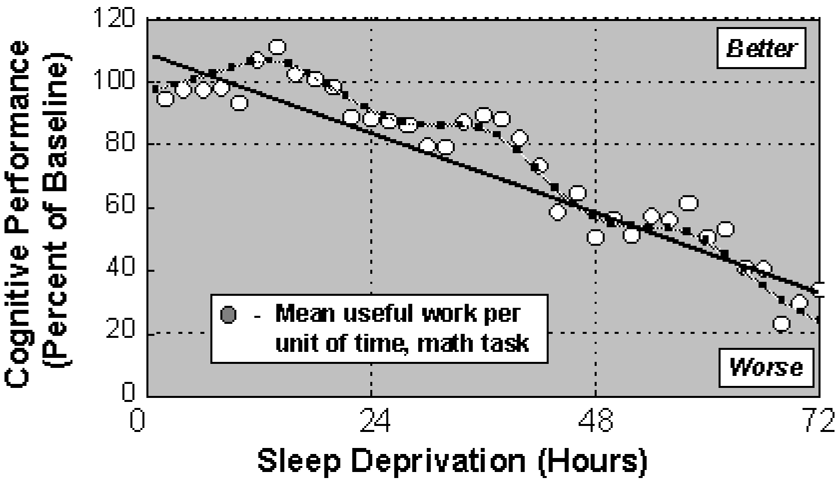
NOTE: Across the night, brief episodes of stage 1 sleep (not illustrated) occur within and between REM and non-REM.

EFFECTS OF SLEEP DEPRIVATION ON COMPLEX MENTAL OPERATIONS

Total Sleep Deprivation

Total sleep deprivation exerts substantial deleterious effects on those complex mental operations (cognitive performance) critical to organizational effectiveness. Figure 2 shows that cognitive performance on a task requiring decisionmaking, short-term memory, and mathematical processing declines by about 25% for every 24 hours of wakefulness. This means that after 72 hours of total sleep deprivation, complex mental performance has degraded by 75%.

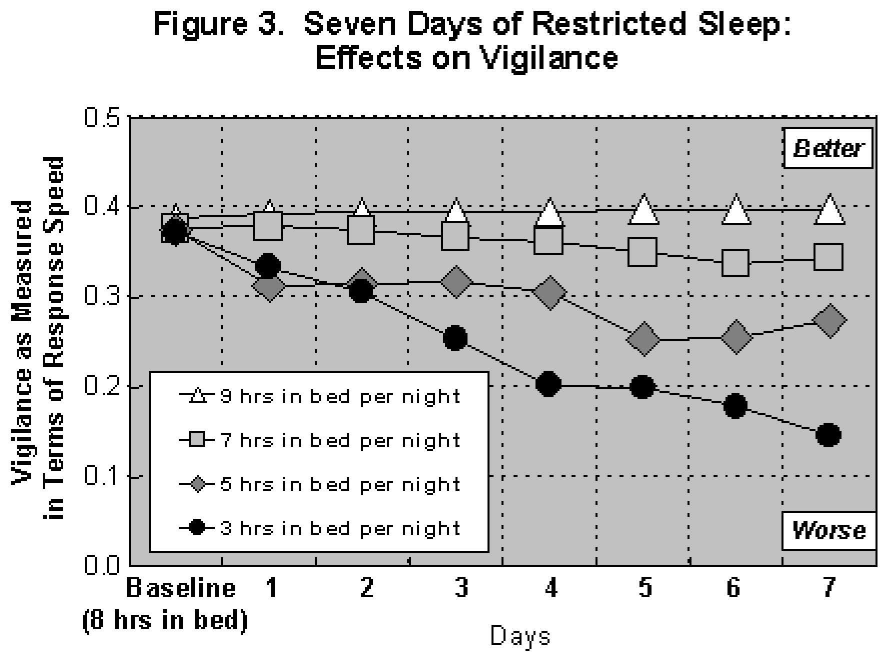
Figure 2. Effect of 72 Hours of Total Sleep Deprivation on Cognitive Performance



NOTE: General trend for performance over time is downward (solid line), but in an undulating pattern that continues to reflect the daily performance rhythm (small squares).

Partial Sleep Deprivation (Restricted Sleep)

If 8 hours of sleep per day sustains maximal mental performance indefinitely, can we get by with less than 8 hours of sleep per day? The answer is that we can, but we will pay a performance penalty for it. Figure 3 shows mental performance over a week for various nightly sleep schedules. Nine hours in bed per night sustains performance. In contrast, 3 hours in bed per night results in immediate and devastating performance deficits that continue to mount over succeeding nights. After a week, performance is reduced by 70% compared to the levels maintained by the group allowed 9 hours in bed per night. Intermediate amounts of sleep (3 hours; 5 hours; 7 hours) also fail to sustain performance. In sum, short-changing sleep decreases productivity.



Disrupted (Disturbed) Sleep

If an individual spends 8-9 hours in bed per night, but during this time sleep is disrupted or fragmented due to noise or attempting to sleep during daytime hours and mental performance and alertness are impaired. The more frequently that sleep is disturbed, the more difficult it is to maintain next-day alertness and mental performance. Disrupting sleep obviously increases wake time, decreasing total sleep time, but it also increasing the amount of less useful stage 1 sleep. Because stage 1 has little or no value for sustaining mental operations, disrupted sleep decreases recuperative sleep time, just the same as restricted sleep or total sleep deprivation.

Summary––Sleep Deprivation Effects

Although total sleep deprivation clearly impairs mental operations, restricting or disrupting sleep also impairs mental operations. In short, whenever recuperative sleep time is reduced, mental operations are impaired—whether owing to total sleep deprivation, partial sleep deprivation, the far less obvious situation in which sleep is disrupted or fragmented.

Sleep deprivation exerts two main behavioral effects. First, it makes the individual more susceptible to falling asleep in a boring or non-stimulating environment—for example, while performing a monotonous task or watching television. Second, even in a stimulating environment where the susceptibility to falling asleep is minimal, sleep deprivation directly impairs higher order mental operations. Tasks most susceptible to the harmful effects of sleep deprivation are those that are not well learned, multifaceted, or requiring an imaginative solution. The case histories discussed earlier provide excellent examples of these types of tasks.

Can an accurate self-estimate of performance in the face of sleep deprivation be obtained from individuals? The answer is no. Sleep-deprived individuals are themselves poor judges of their own cognitive performance—this is perhaps not surprising since those areas of the brain involved in self-assessment are impaired by sleep deprivation (discussed below).

EFFECTS OF SLEEP DEPRIVATION ON REGIONAL BRAIN

Results of brain imaging (positron emission tomography or PET) studies during sleep deprivation have revealed that sleep deprivation decreases brain activation. More critical is that activation is most decreased in specific brain areas—those mediating the ability to maintain alertness and vigilance and those mediating higher order mental operations such as situational awareness, adaptability, mental agility, judgment, initiative, anticipation, and planning. These qualities are crucial for organizational effectiveness.

During sleep itself, those brain regions most affected by sleep deprivation are also deactivated to the greatest extent. Thus, the primary function of sleep may be to restore and sustain brain regions that (1) mediate the ability to maintain wakefulness under non-stimulating conditions and (2) mediate higher order mental operations. Results of the brain imaging studies are consistent with previously established performance effects of sleep deprivation.

Consequences for Job Performance

As indicated earlier, sleep deprivation exerts two main effects: it decreases the ability to resist sleep under boring, repetitive, and non-stimulating circumstances; and it also directly impairs mental performance even in a stimulating environment. Thus whether a job is likely to be affected by sleep deprivation depends on the extent to which it involves these components. Examples of tasks that are likely to be very sensitive to sleep deprivation include manning a tactical screening position during hours of darkness, monitoring data displays for critical levels, monitoring output for quality control purposes, and sentry or patrol duties.

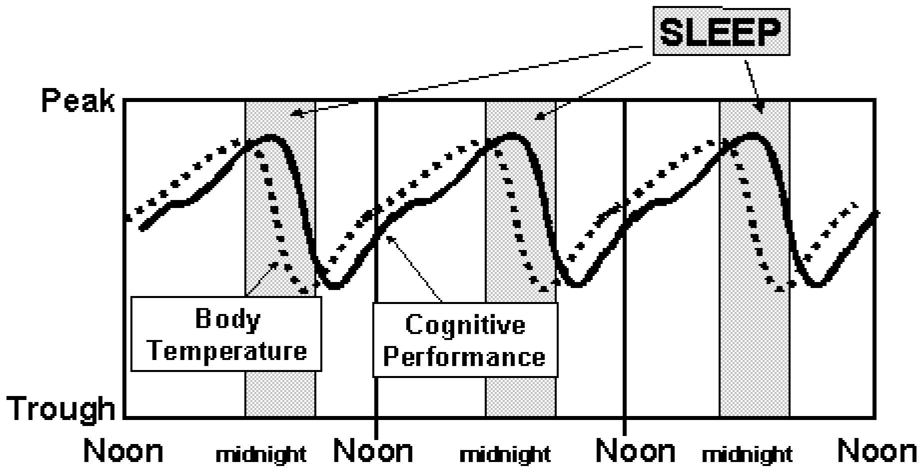
On the surface, all of these tasks appear to be relatively simple, easily learned, and thus resistant to sleep deprivation. However, these tasks require all of the mental processes most affected by sleep deprivation. First, all embody conditions that increase the likelihood of falling asleep. They are generally long-duration tasks that are very infrequently punctuated with arresting events, and therefore present very little mental or physical stimulation. Second, should a critical event occur, these tasks then involve complex mental operations. As an example, manning a screening position calls for discriminating friend from foe followed by decision making: Destroy the foe? Take action to restore levels to non-critical values? Pull the unacceptable output off the line?

What about individuals at higher organizational levels (e.g. command and control)? Even if they are sleep-deprived, they are not likely to fall asleep in a high op-tempo environment, for example, the commander in the tactical operations center or the executive in a high-pressure meeting with the CEO. Nonetheless, their decisionmaking skills are impaired and they will be less likely to generate novel solutions to problems. Instead, they are likely to continue tried and true solutions even in the face of evidence that these solutions are not working. They also will be less likely to keep up with continuously evolving situations and make sense of and integrate newly emerging information. They may simply ignore or downplay conflicting information.

TIME-OF-DAY (CIRCADIAN) EFFECTS ON PERFORMANCE AND SLEEP

Independent of an individual’s sleep history, time-of-day (or circadian phase) affects cognitive performance, alertness, and many physiological variables. Figure 4 illustrates the usual relationships among body temperature, complex mental operations, and sleep. Peaks and troughs in body temperature slightly precede those of cognitive performance. Sleep generally occurs across the lowest points in body temperature and cognitive performance.

Figure 4. Relationships among Sleep, Body Temperature, and Cognitive Performance



Complex Mental Operations

The circadian rhythm for cognitive performance (Figure 4) is similar to the rhythm for body temperature, peaking during the period 10:00 p.m. to midnight, and entering a trough at approximately 6:00 a.m. to 10:00 a.m. A slight decrement in alertness and complex mental operations in the early to mid-afternoon hours (1:00 p.m. to 3:00 p.m.) also occurs, although the overall trend across the day is toward improved performance. The daily rhythm in complex mental operations is maintained during sleep deprivation, as is body temperature rhythm, and may vary within a single day by 20% (peak to trough). In short, independent of the amount of sleep, time of day strongly influences complex mental operations.

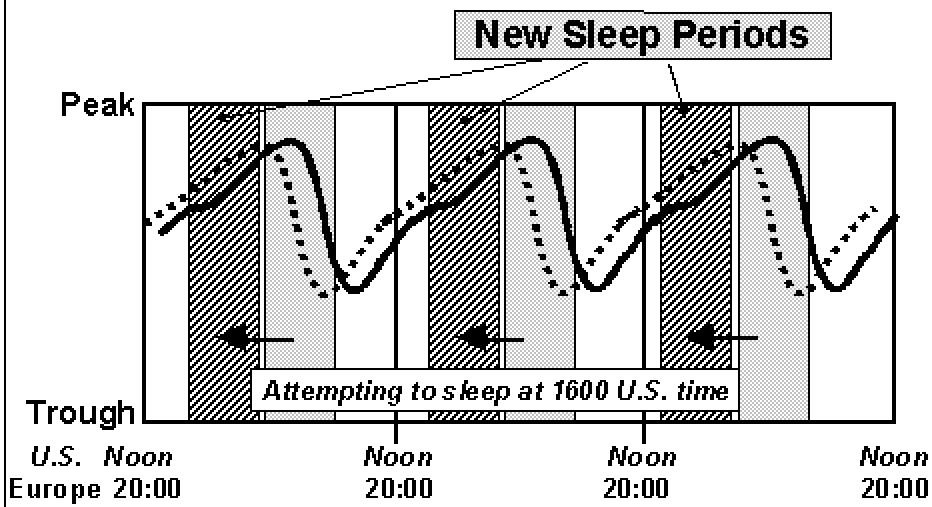
Sleep Tendencies

The propensity to sleep is highest just after the late evening peak in body temperature, and this is when most individuals initiate sleep (Figure 4, gray bars). Thus the bulk of sleep generally accrues during the subsequent minimums in both body temperature and mental performance rhythms. Sleep is typically terminated in the early morning hours, as body temperature begins to rise. For reasons not yet understood, individuals are more likely to fall asleep and remain asleep during the period when body temperature is at its lowest.

Time Zone Shifts

Travel between time zones and shift work result in a realignment of sleep, body temperature, and cognitive performance rhythms. In the example depicted in Figure 5, showing eastward travel from the United States to Europe, the new sleep period (cross-hatched bars) falls across the ascending limb of the body temperature rhythm, overlapping with peak body temperature. Sleep during this body temperature phase is characterized by frequent awakenings and nonrecuperative stage 1 sleep. Consequently, the individual is partially sleep deprived (possibly the underlying cause of jet lag). Also, the desired period of wakefulness (i.e., the workday in the new time zone) occurs when circadian rhythms dictate that cognitive performance is at its worst. These effects occur in addition to direct effects of partial sleep deprivation on mental operations. West-bound travel results in similar problems, and adaptation and resynchronization of cognitive performance and alertness rhythms to a new time zone can take several days.

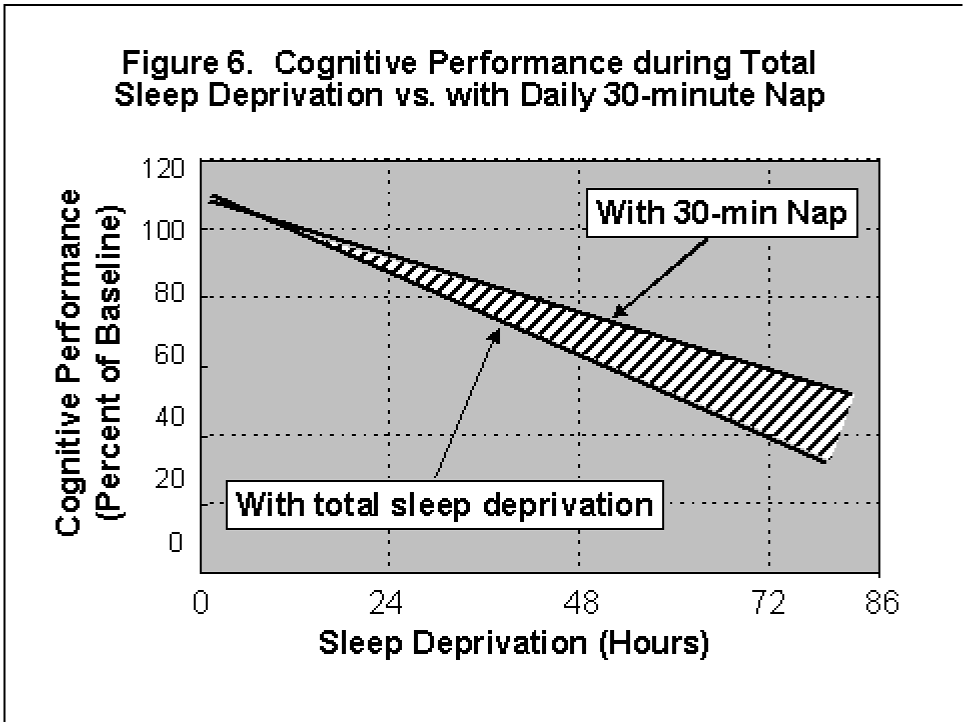
Figure 5. Relationships among Sleep, Body Temperature, and Cognitive Performance following an 8-hour time zone advance (U.S. to Europe)



Scientific literature and the popular press are filled with strategies for "shifting circadian rhythms", although it is often unclear which "rhythm" is to be shifted. Some of these shift strategies are discussed below e.g. melatonin administration. In some cases they have been know to improve *subjective* feelings (e.g., feelings of fatigue and nausea), but none have been shown to improve *objectively measured* mental operations. On the other hand, evidence is overwhelming that improving and increasing sleep time has objective, positive effects on mental operations. The strategies discussed below include both non-pharmacological and pharmacological approaches to improving sleep when persons are required to sleep at odd times or under non-sleep-conducive conditions. Also discussed are means for improving alertness and performance on a short-term basis when sleep is impossible.

TAKING NAPS: A NON-PHARMACOLOGICAL MEANS FOR INCREASING OR IMPROVING SLEEP

The term nap generally refers to any sleep period outside of the main sleep period. Napping can constitute an excellent strategy for increasing total daily sleep time, so long as the individual actually *sleeps* during the napping period. Substantial benefit is derived from even small amounts of sleep. Figure 6 shows that after 72 hours, individuals allowed only 30 minutes per day to sleep, or a total of 1.5 hours sleep during the 72-hour period, performed nearly 25% better than subjects getting no sleep at all. The daily 30-minute nap in those individuals was extremely concentrated and thus efficient. Subjects spent nearly the entire 30 minutes in deeper sleep stages, with almost no time awake or in stage 1 sleep.



Thus even short bouts of sleep will improve performance. Thirty minutes of sleep per day reduces the rate of cognitive performance degradation from 25% per day to 17% per day. However—to repeat— the key is that a nap must actually consist of sleep, either stage 2, single wave, or REM. Also, as long as they contain *equal sleep amounts*, several short sleep bouts will be just as restorative as one long sleep bout. Although quiet rest during wakefulness may make the individual feel better, it does not restore or sustain mental operations. Overall it is recommended that individuals sleep as long and as often as needed to obtain 8 hours of it.

Whether a nap will be beneficial depends upon such factors as timing and noise, light levels, ambient temperature. Factors affecting sleep are outlined in Table 1.

Although post-sleep performance impairments or "sleep inertia" may occur upon awakening from a nap or any sleep period, such grogginess is of relatively short duration and usually dissipates within 20 minutes. Under most circumstances, the benefits of sleep will far outweigh the short-term risk of impaired post-sleep performance.

FACTOR	CONTRIBUTION
Timing of Sleep Period	• Sleep periods timed for early morning (near body temperature trough) or early afternoon (post-lunch dip) more likely to result in restorative sleep.
Ambient Noise	• Intermittent noises (e.g., telephone ring) more disruptive than continuous, monotonic noise. • Use constant "white noise" (e.g., fan) and/or ear plugs to mask intermittent sounds. • "Relaxation tapes" *prior* to sleep may increase feelings of relaxation, but do not objectively improve sleep. •

	Avoid presenting anything during sleep period; may be disruptive (e.g., audio tapes for "learning while asleep").
Ambient Light Levels	- Light is source of stimulation, making it difficult to fall asleep. - Darken sleep area to extent possible. - Sleep masks or eye patches block remaining ambient light.
Ambient Temperature	- Small deviations above or below comfort zone may disrupt sleep. - Provide clothing/blankets in cold environments. - Provide fans in hot environments (can double as source of white noise).
Warm Bath	- Warm bath may increase subsequent sleep by raising brain temperature. - Physical exercise exerts similar effects but can be disruptive if of high intensity just prior to bedtime.
Stimulants (e.g., caffeine)	- If still in body, may increase wakefulness and stage 1 (i.e., decrease nap's recuperative value).
Sedatives (e.g., alcohol)	- Even though sedatives increase feelings of drowsiness and may hasten sleep onset, some (especially alcohol) "fragment" sleep (increase wakefulness and stage 1). - Individuals may be unaware that sleep is disrupted—particularly with alcohol, brief arousals to stage 1 and awakenings are not remembered the next day, leading to the perception that sleep was not disrupted. - Withdrawal from substances may disrupt sleep as much as the substance itself.

Dietary Constituents

- No objective evidence that particula dietary constitue objective improve sleep in otherwis normal, healthy individua
- Some dietary substanc may *subjectiv* improve

sleep.

Table 1. Factors affecting sleep during designated sleep periods.

PHARMACOLOGICAL MEANS FOR INCREASING OR IMPROVING SLEEP

Even when time is available, sleep may be unlikely—for example at midmorning or when the quality of the sleep environment is poor. Under these conditions, non-pharmacological strategies may not be sufficient. Improving sleep with the aid of a sleep-inducing agent may be a solution.

The ideal sleep-inducing agent would commence working immediately, increase recuperative sleep time, and possibly cease working after a short period if the sleep period available was of limited duration. Most important, the ideal sleep-inducing agent would not impair performance after awakening, that is, there would be no drug hangover effect. Many individuals hesitate to take sleep-inducing agents out of fear of the hangover effect.

The sleep-inducing agents triazolam (brand name Halcion), zolpidem (brand name Ambien), and temazepam (brand name Restoril) have been tested extensively both in the laboratory and in the field. All of these agents act similarly, exerting their effects in the same areas of the brain, and reaching peak blood concentrations within approximately 1.5 hours. Triazolam and zolpidem display a shorter duration of action than temazepam, probably because they are eliminated from the body more rapidly. However, a drug's elimination rate from the body (half-life) does not necessarily predict its duration of action on sleep or mental operations (see below).

Laboratory Evaluations

Laboratory evaluations reveal that both triazolam and zolpidem improve sleep under simulated troop transport conditions by reducing amounts of wake and stage 1 (Figure 7). However, twice the currently recommended dose of both drugs is required for this effect (0.5 mg triazolam and 20 mg zolpidem). Additionally, a worst-case scenario simulation like awakening and confronting a tough mental challenge at these sleep-inducing doses, both drugs impair complex mental operations at peak effect, occurring 1.5 hours after administration (Figure 8). In addition, 0.5 mg triazolam impairs mental performance for at least 6 hours post-dose—an effect not predicted based on the drug's half-life of approximately 2 hours.

Figure 7. Effects of Triazolam vs. Zolpidem

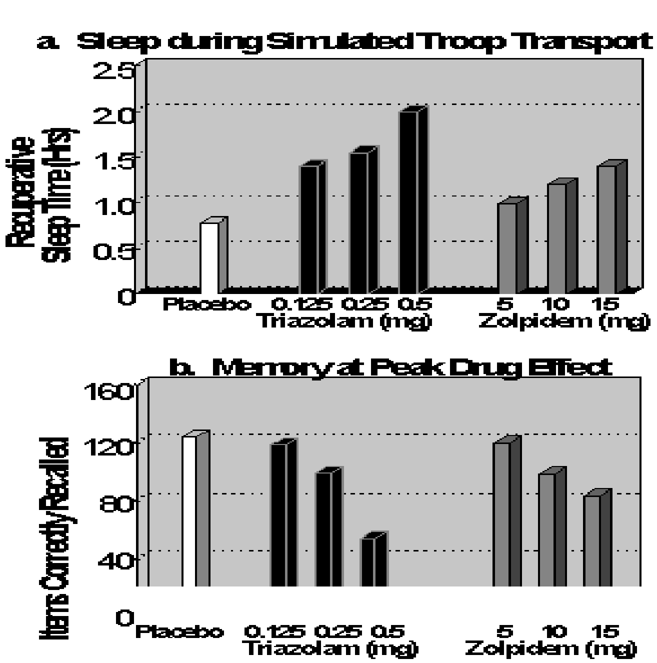
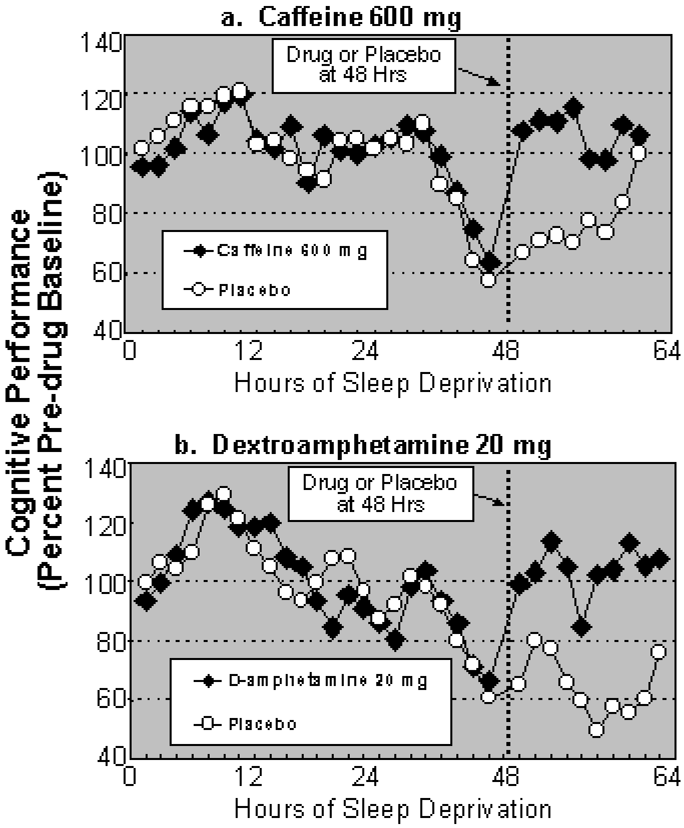


Figure 8. Stimulant Drugs:
Effects on Cognitive Performance During
64 Hours of Sleep Deprivation



Field Studies

Triazolam has been tested in the field. In a study of Operation Bright Star, 0.5 mg triazolam ,twice the currently recommended dosage, did not improve daytime sleep in soldiers during a U.S.-to-Europe deployment, yet impaired complex mental operations up to 8 hours after administration. Although the results suggested that triazolam, at least the 0.5 mg dose, is unsuitable for use during long-range aerial deployments, two key features of the study could account for the poor outcome. First, the in-flight hot meal service started three hours after soldiers had taken the drug or the placebo. Second, even after they had eaten, soldiers had to pass other trays down the line as the meals came out of the two microwave ovens on board. For approximately 3 to 6 hours after the drug was administered, no one slept. Soldiers were required to stay awake at the very time when they should have been allowed to take advantage of the drug's peak sleep-inducing effect. Results of this field study indicated that sleep-inducing agents might be contraindicated during deployment if soldiers will not have an opportunity to sleep relatively undisturbed.

In a field study at Ft. Lewis, triazolam in 0.5 mg and 0.25 mg dosages improved sleep in ranger rifle platoons sleeping in the cold but otherwise not disturbed. However, 0.5 mg triazolam (but not 0.25 mg) impaired performance 4 hours post-dose. Importantly, at 24 hours post-dose, soldiers given 0.25 mg triazolam performed significantly better on complex mental tests than a group given no drug at all. This study again demonstrates the value of relatively small increments of sleep, showing that the benefits derived are long-lasting. Of note in this field study is that triazolam caused some soldiers to fall asleep even before they zipped themselves into their sleeping bags, thus requiring the study investigators to secure the soldiers in their sleeping bags to protect them against the sub-freezing temperatures. Results from this field study thus suggested that sleep-inducing agents might be contraindicated in harsh environments, especially when soldiers cannot be monitored closely.

Melatonin

Some interesting claims have been made in behalf of the pineal hormone melatonin, namely, that oral-ingested, synthetic melatonin improves sleep and readjusts circadian rhythm. It is often unclear, however, in such reports as to exactly which rhythm is affected, e.g., body temperature, alertness, or performance.

Does synthetic melatonin work? The answer depends upon what one wants to accomplish. For example, after travel between time zones, melatonin hastens resynchronization of body temperature rhythm with new local time. However, whether rapidly resynchronizing body temperature has any practical significance, especially in terms of mental performance, has not been established. Other effects of melatonin are summarized in Table 2. Of note, melatonin's side effects, long-term effects, and minimum effective dosage have not been established.

Sleep-Inducing Agents––Summary and Conclusions

At sufficient dosages, prescription sleep-inducing agents can improve sleep in an operational environment. When sleep-inducing agents are administered, precautions must be taken to ensure that the sleep period is protected by maintaining reasonable control over the sleep environment and providing sufficient down time, and that a sleep monitor is on hand, particularly in hazardous environments. In most instances, sleep-inducing agents can be administered according to labeling instructions (for example, 10 mg zolpidem, 30 minutes prior to bedtime). Higher doses may be required in young, healthy adults or under particularly non-sleep-conducive conditions. Despite popular press sensationalism, when properly used according to packaging directions and considering the contraindications highlighted above, sleep-inducing agents are both safe and effective.

The performance benefits of obtaining sleep must be weighed against the possible risks associated with use of sleep-inducing agents. Despite claims by some drug manufacturers that a particular sleep-inducing agent causes fewer negative side effects than other agents, the literature clearly shows that all sleep-inducing agents, *at sleep-inducing doses*, impair mental performance at their peak sleep-inducing effect. Although some new sleep-inducing agents (e.g. zolpidem and zopiclone) are in a different drug class than the standard sleep-inducing agents (e.g. temazepam and triazolam), these newer agents exert their effects in the same areas of the brain as the standard agents. Current recommendations for using sleep-inducing agents are summarized in Table 2.

Sleep-Inducing Agents––Future Directions

The capability for immediate reversal of sleep-inducing agents in an emergency situation would be desirable. Although stimulants like caffeine may seem an obvious choice, they are only partially effective, most likely because they act at brain sites different from sleep-inducing agents. Recently, the agent flumazenil (brand name Romazicon) was shown to block the most widely used sleep-inducing agents' effects completely and rapidly within 3 minutes of intravenous administration and left individuals alert and able to perform at normal levels. Flumazenil causes no measurable side effects and is not a stimulant like caffeine and is ineffective during sleep deprivation. Flumazenil has been in use for several years as an antidote to benzodiazepine anesthesia and overdose. For sleep management in the operational environment, a fieldable, dual-drug system for safe sleep induction using effective sleep-inducing agents such as triazolam or zolpidem, electively followed by rapid sleep termination and performance restoration using flumazenil would be ideal. However, flumazenil is currently marketed only in intravenous form and development of an approved orally-administered formulation would be required.

Finally, melatonin has some slight sleep-promoting properties in that it decreases time taken to fall asleep. It may be that a combination of melatonin plus a sleep inducer (e.g. zolpidem) would allow for a lower dose of the sleep inducer to be administered while still improving sleep—and resulting in less post-sleep performance impairment.

AGENT	USE and PRECAUTIONS
Prescription Agents: Triazolam, Zolpidem, Temazepam, Zopiclone, etc.	• Administer according to packaging directions to start. • Higher doses may be required in young, healthy adults and/or under non-conducive conditions. • Combine with non-pharmacological strategies. • Ensure sufficient down time (e.g., at least 6 hrs following triazolam or zolpidem; 10 hrs following temazepam). • Monitor individuals continuously in harsh environments. • Agents impair performance if still in body. • Not for long-term (e.g., greater than 10 days) use – agents may lose effectiveness (i.e., development of "tolerance"); withdrawal may impair sleep. •

	Though available by prescription, sleep-inducing agents are controlled substances.
Melatonin	- Increases subjective feelings of sleepiness - May improve subjective feelings of sleep quality - Shortens time taken to fall asleep - Does not increase recuperative sleep time - May impair performance if still in body - Effective dose range not established - Purity/additives of over-the-counter preparations may vary
Over-the-Counter Agents: Sominex, Nytol	- Increases subjective feelings of sleepiness - May improve subjective feelings of sleep quality - Little effect on recuperative sleep time
Other Sedative Agents: Alcohol, Antihistamines	- Increases subjective feelings of sleepiness - May improve subjective feelings of sleep quality - May actually degrade sleep, reducing recuperative sleep time

Table 2. Pharmacological strategies for improving sleep under non-sleep-conducive conditions.

NON-PHARMACOLOGICAL STRATEGIES FOR INCREASING/IMPROVING COMPLEX MENTAL PERFORMANCE AND ALERTNESS

Non-pharmacological strategies for improving complex mental performance and the ability to remain awake include bright light exposure and a host of behavioral measures. For the most part, these strategies are minimally effective and only for short periods, and often improve subjective feelings of alertness without improving complex mental performance. These strategies are outlined in Table 3.

FACTOR	NOTES
Bright Light Exposure	- Timed exposure probably impractical in most operational settings – "appropriate" v. "inappropriate" light exposure times determined by factors not easily measured in the workplace. - Limiting exposure is feasible (e.g., wear light-blocking sunglasses in the morning after night shift work). - No evidence that bright light exposure objectively, substantially, and consistently improves mental operations outside of controlled laboratory setting.
Behavioral Strategies: Cold Air, Noise (e.g., loud music), Physical exercise	- Improve subjective feelings of alertness - Effects on performance and ability to stay awake are short-lived (less than 30 min)

Table 3. Non-pharmacological strategies for improving complex mental operations and the ability to remain awake.

Finally, numerous patents have been awarded for methods and devices designed to detect sleepiness and then nonpharmacologically heighten alertness, for example, devices to detect head nods and produce an alerting stimulus such as a vibration or loud noise. The problem with all such devices is sensitivity. That is, by the time the device detects a critical event (e.g. the individual's head has begun to nod), an error or accident has probably already occurred. Performance errors due to sleep deprivation begin to occur well before the individual exhibits overt signs of sleepiness.

PHARMACOLOGICAL STRATEGIES FOR INCREASING/IMPROVING COMPLEX MENTAL PERFORMANCE AND ALERTNESS

Although sleep is the best means to combat sleep deprivation, operational exigencies can preclude adequate sleep. Under these circumstances, strategies for augmenting mental performance can be implemented. Currently, the most effective strategy for improving mental performance during sleep deprivation is the administration of central nervous system stimulants. Agents tested in our and other laboratories include caffeine, dextroamphetamine (often referred to as d-amphetamine), and nicotine. Information about these agents is summarized in Table 4.

AGENT	USE, FORMULATIONS, and PRECAUTIONS
Caffeine	• Caffeine 600 mg (about 6 cups coffee) improves mental performance and alertness when administered after 48 hours total sleep deprivation. • Available commercially over-the-counter in tablets such as Vivarin® or No-Doz® and can be administered according to packaging directions to start. • Gum formulation (50 mg caffeine per stick available commercially over-the-counter as StayAlert®) may be more rapidly absorbed than tablets, allowing for a lower dose. • May cause jitteriness, nervousness, nausea, and talkativeness. Anxiety • May interfere with sleep if a sleep opportunity becomes available after administration. • Tolerance may develop with repeated use.
Dextroamphetamine	• Dextroamphetamine 20 mg improves mental performance and alertness when administered after 48 hours of total sleep deprivation. • Available by prescription as Dexedrine® (controlled substance) • May cause jitteriness, nervousness, nausea, talkativeness, anxiety • May interfere with sleep (see above, caffeine) • Tolerance may develop with repeated use. • Possesses some abuse potential
Nicotine	• Does not improve mental performance or alertness when administered after 48 hours of total sleep deprivation. • May cause nausea.

Table 4. Pharmacological strategies for improving mental operations and alertness during total/partial sleep deprivation.

Caffeine

When administered as a single oral dose after 48 hours of sleep deprivation, caffeine restores complex mental operations.

Caffeine in 150, 300, and 600 mg dosages is equally effective for approximately 1 hour post-administration, but only 600 mg sustains restored performance for at least 4 hours post-administration. Caffeine in a 600 mg dosage also increases the ability to remain awake in a non-stimulating environment.

Caffeine interferes with sleep even 12 hours after ingestion. However, whether caffeine-impaired sleep translates into next-day performance impairments as a result of partial sleep deprivation depends on the total amount of actual recuperative sleep time obtained. For example, in one study 300 mg of caffeine reduced recuperative sleep duration by an hour compared to a placebo group. However, reduced sleep did not translate into next-day performance impairments because the overall amount of recuperative sleep obtained was more than seven hours. Had the sleep period been shorter, the impact of a 1-hour reduction in sleep may have been more salient. Similarly, had the sleep period commenced nearer to caffeine administration (e.g., 4 hours after administration versus 12), or had the sleep deprivation period been shorter, caffeine's effects on sleep may have been more striking. The long sleep deprivation period drastically increased sleep propensity, partially offsetting caffeine-induced decrements in sleep propensity.

In sum, caffeine at a 600 mg dosage effectively restores the ability to remain awake under boring, non-stimulating conditions, and it restores the ability to perform complex mental operations. However, caffeine also produces some mild subjective effects (both negative and positive perception), and can interfere with subsequent sleep.

Dextroamphetamine

When administered after 48 hours of sleep deprivation, 20 mg of dextroamphetamine is effective for restoring mental operations to baseline levels (Figure 10), and it increases alertness in non-stimulating environments.

Subjectively, dextroamphetamine improves self-ratings of energy level, vigor, and alertness. It also interferes with recovery sleep; however, results from a U.S. Army Aeromedical Research Laboratory study show that the recovery sleep-reducing effects of dextroamphetamine do not translate into measurable deficits in next-day performance. Again, however, the overall amount of recuperative sleep obtained even with dextroamphetamine in that study was more than 7 hours. As with caffeine, the impact of a 1-hour loss may have been more salient had the sleep period been shorter, had the sleep deprivation period been shorter, or had the sleep period commenced closer to the time of drug administration. In any event, caffeine 600 mg and 20 mg dextroamphetamine restore cognitive performance to levels seen prior to total sleep deprivation.

Other Agents

Other agents with alleged stimulant-like properties (mostly subjective) have been evaluated for effectiveness in counteracting mental performance and alertness impairments during sleep deprivation. Nicotine is ineffective for combating sleep-deprivation-induced mental performance or alertness degradation. Nicotine does not improve mood and causes nausea in some individuals. Many Ranger students use smokeless tobacco during Ranger training. One graduate of Ranger school recounted how Ranger students would place smokeless tobacco in their eyes to stay awake. They also would swallow tobacco juice to keep them going, hence its name "go-juice." However, it is important to note that although nicotine may have resulted in improved subjective alertness, go-juice is a poor makeshift for restoring or maintaining complex mental performance. In fact, there may be dangers associated with using substances such as nicotine, since such substances may increase feelings of alertness without actually improving mental performance to a comparable extent.

Flumazenil has also been evaluated for potential performance-restoring effects during sleep deprivation. However, flumazenil is completely ineffective and possesses no stimulant properties. Its effectiveness for reversing the effects of sleep-inducing agents is due exclusively to its ability to counteract the effects of specific sleep-inducing agents.

Stimulant Agents––Future Directions

Modafinil (brand name Provigil) is a new stimulant agent currently indicated for improving alertness in narcolepsy, a sleep disorder characterized by excessive, uncontrollable daytime sleepiness. Claims have been made that modafinil does not act at the same brain receptors as either caffeine or amphetamine, but in fact its mechanism of action is not known. Moreover, though modafinil improves alertness in narcoleptics, whether it substantially improves complex mental performance in sleep-deprived normal individuals has not been demonstrated.

Other questions that would need to be answered include whether modafinil has favorable tolerance and abuse-potential characteristics, whether it interferes with post-sleep-deprivation recovery sleep, and if it does so interfere, whether such interference translates into performance deficits. Preliminary results indicate that at the doses tested, modafinil is no more effective than caffeine in improving complex mental performance during sleep deprivation.

SUMMARY AND CONCLUSIONS

Sleep sustains effectiveness. Sleep deprivation, whether total or partial, impairs the ability to stay awake under boring or non-stimulating conditions. Even under highly stimulating or challenging conditions, sleep deprivation impairs complex mental operations, including the ability to judge one's own level of mental effectiveness.

Decreased activation of specific brain areas underlie sleep deprivation-induced mental performance and alertness impairments. However, the reason for these regional deactivations during sleep loss remains a mystery. Once these mechanisms are understood, far more effective methods for managing sleep and alertness might be developed. For now, both pharmacological and non-pharmacological methods can improve sleep under non-sleep-conducive conditions. When short-term sleep deprivation is inevitable, only pharmacological means have been demonstrated to effectively and consistently restore and maintain complex mental performance and alertness.

When viewed at the level of the organization, one individual's poor performance may not become evident until (1) the declining performance falls outside of a critical envelope; or (2) the performance of others also begins to decline, causing a synergistic failure. To deal with either situation effectively, sleep must be measured at the individual level. This will allow effective sleep management strategies to be implemented at both the individual and organizational levels, as appropriate.

Endnotes

1. For earlier treatments of the sleep deprivation problem in an operational setting,see Frederick J. Manning, "Continuous Operations in Europe: Feasibility and the Effects of Leadership and Training," *Parameters*, Vol. 9, September 1979, pp. 8-17; and Jonathan Shay, "Ethical Standing for Commander Self-Care: The Need for Sleep," *Parameters*, Vol. 28, No. 2, Summer 1998, pp. 93-105.
2. W. C. Dement, and C. Vaughan, *The Promise of Sleep*, New York: Delacorte Press, 1999, p. 53.
3. G. L. Belenky, J. A. Martin, and S. C. Marcy, After-action critical incident stress debriefing and battle reconstruction following combat. In J. A. Martin, L. R. Sparacino, and G. L. Belenky, eds., *The Gulf War and Mental Health: A Comprehensive Guide*, Westport, CT: Praeger, 1996, pp. 105-113.